



US010072853B2

(12) **United States Patent**
Chaudhry et al.

(10) **Patent No.:** **US 10,072,853 B2**
(45) **Date of Patent:** **Sep. 11, 2018**

(54) **WATER HEATER HAVING A SUPPLEMENTAL PHOTOVOLTAIC HEATING ARRANGEMENT**

(58) **Field of Classification Search**
None
See application file for complete search history.

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(*) Notice: Subject to any disclaimer, the term of this patent is extended or adjusted under 35 U.S.C. 154(b) by 114 days.

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(21) Appl. No.: **14/986,871**

(57) **ABSTRACT**

(22) Filed: **Jan. 4, 2016**

A water heater is provided having an insulated tank having a water inlet and a water outlet, and further defining an interior volume to contain a quantity of water. A primary heating arrangement applies heat energy to the water so as to heat the water. In addition, the primary heating arrangement is configured to maintain the water during standby periods between upper and lower set point temperatures. A supplemental heating arrangement is operative to supply additional heat energy to the water in order to lessen energy usage by the primary heating arrangement during the standby periods. In accordance with a preferred embodiment, the supplemental heating arrangement includes at least one photovoltaic panel and a supplemental heating element. Control electronics are operatively interposed between the at least one photovoltaic panel and the supplemental heating element.

(65) **Prior Publication Data**

US 2016/0195284 A1 Jul. 7, 2016

Related U.S. Application Data

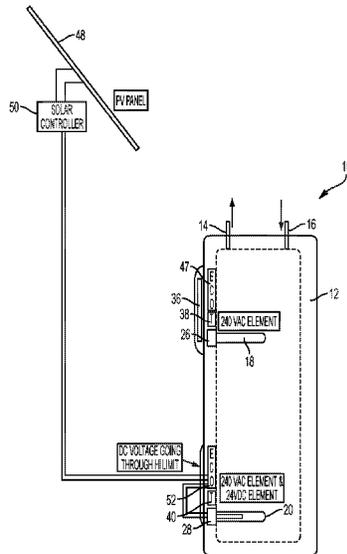
(60) Provisional application No. 62/099,529, filed on Jan. 4, 2015.

(51) **Int. Cl.**
F24H 1/18 (2006.01)
F24D 19/10 (2006.01)

(Continued)

(52) **U.S. Cl.**
CPC **F24D 19/1075** (2013.01); **F24D 3/005** (2013.01); **F24D 17/0021** (2013.01);
(Continued)

25 Claims, 5 Drawing Sheets



(51)	Int. Cl. <i>F24D 3/00</i> (2006.01) <i>F24D 17/00</i> (2006.01) <i>F24H 1/20</i> (2006.01) <i>F24H 9/20</i> (2006.01)	8,220,453 B2 7/2012 Bourke 8,813,687 B2 8/2014 Chaudhry 8,897,632 B2 * 11/2014 Flohr F24H 9/2021 392/441 8,909,033 B2 * 12/2014 Kreutzman F24D 19/1048 219/482
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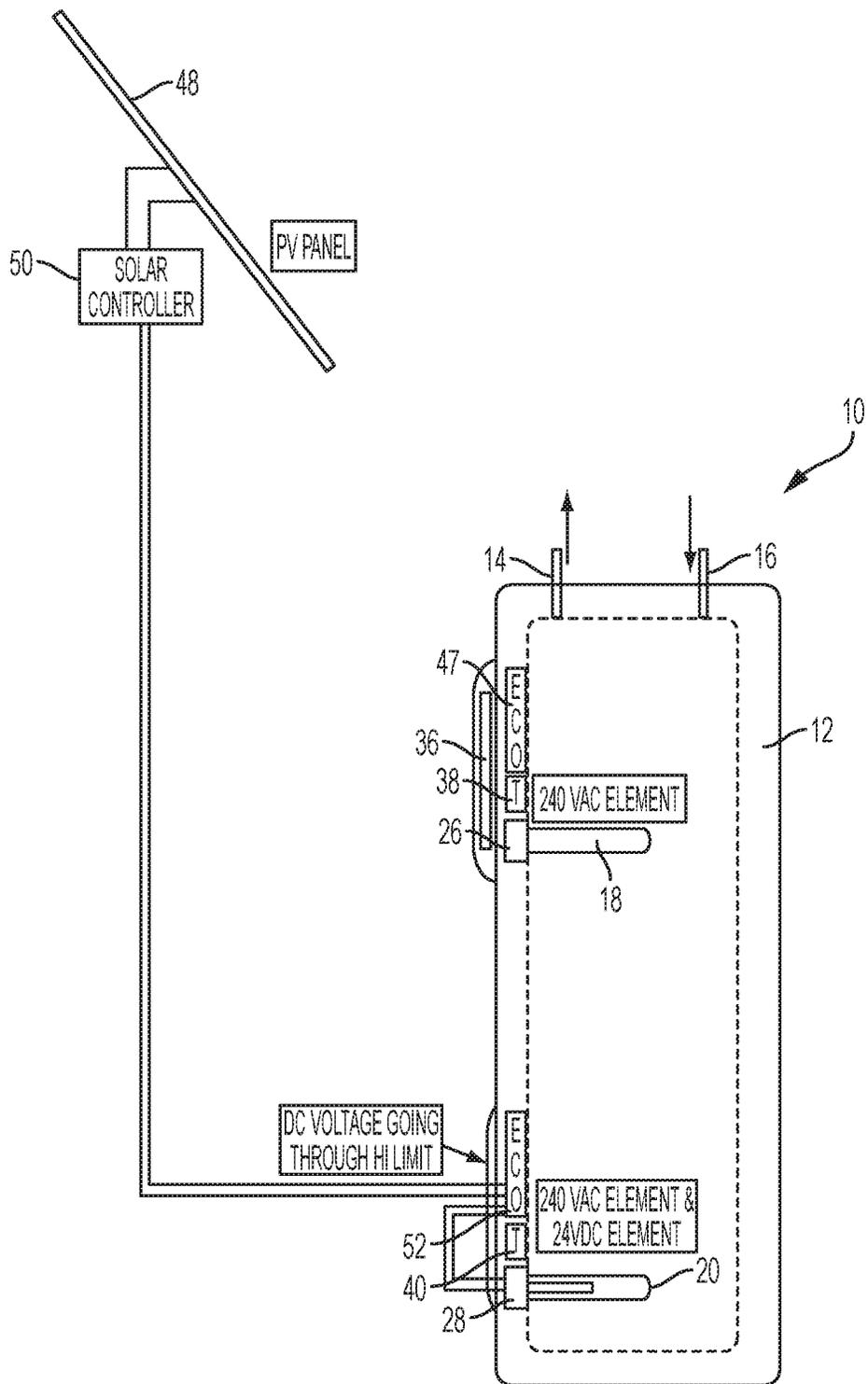


FIG. 1

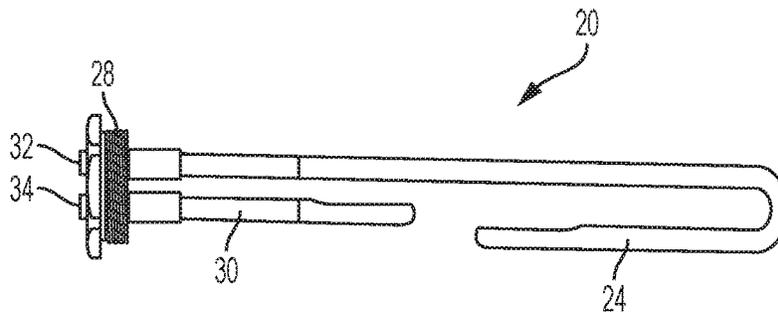


FIG. 3

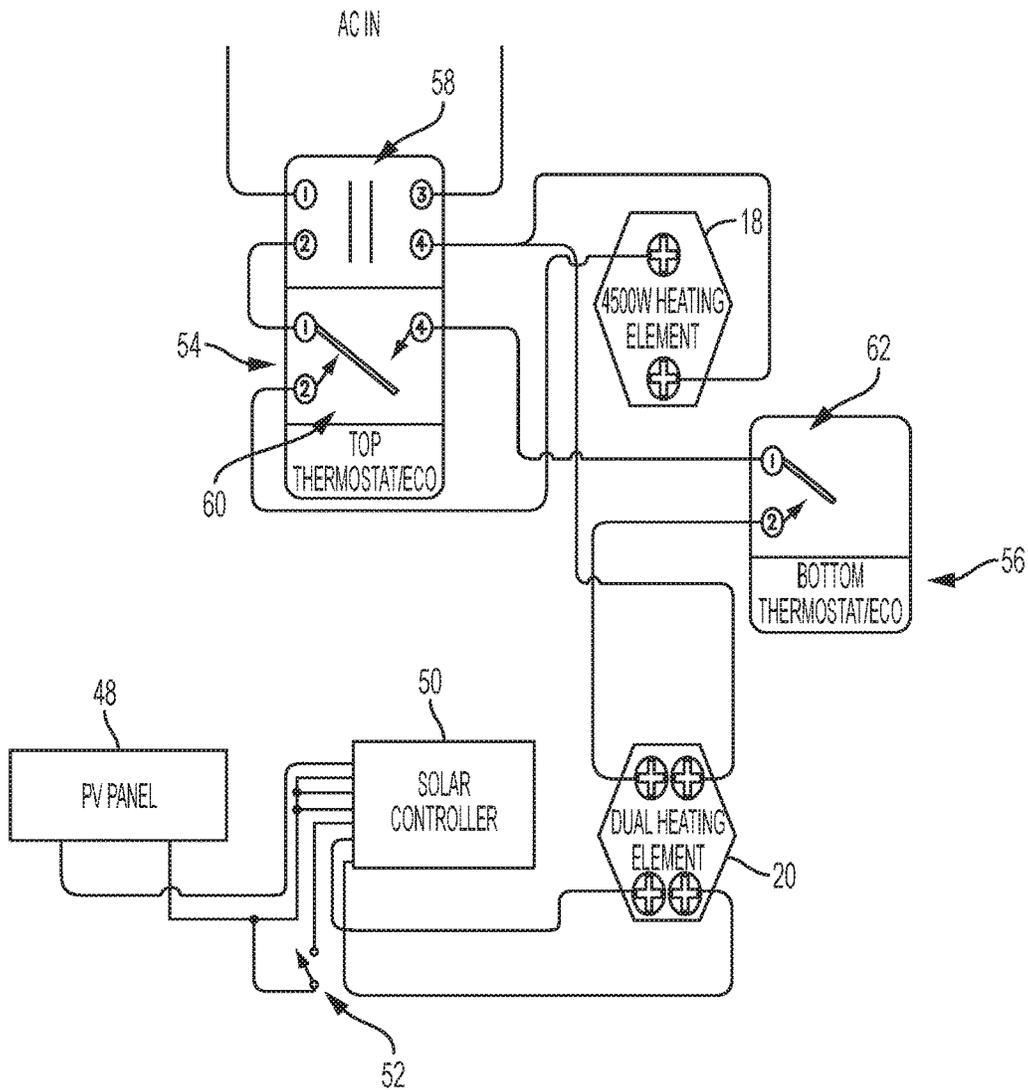


FIG. 4

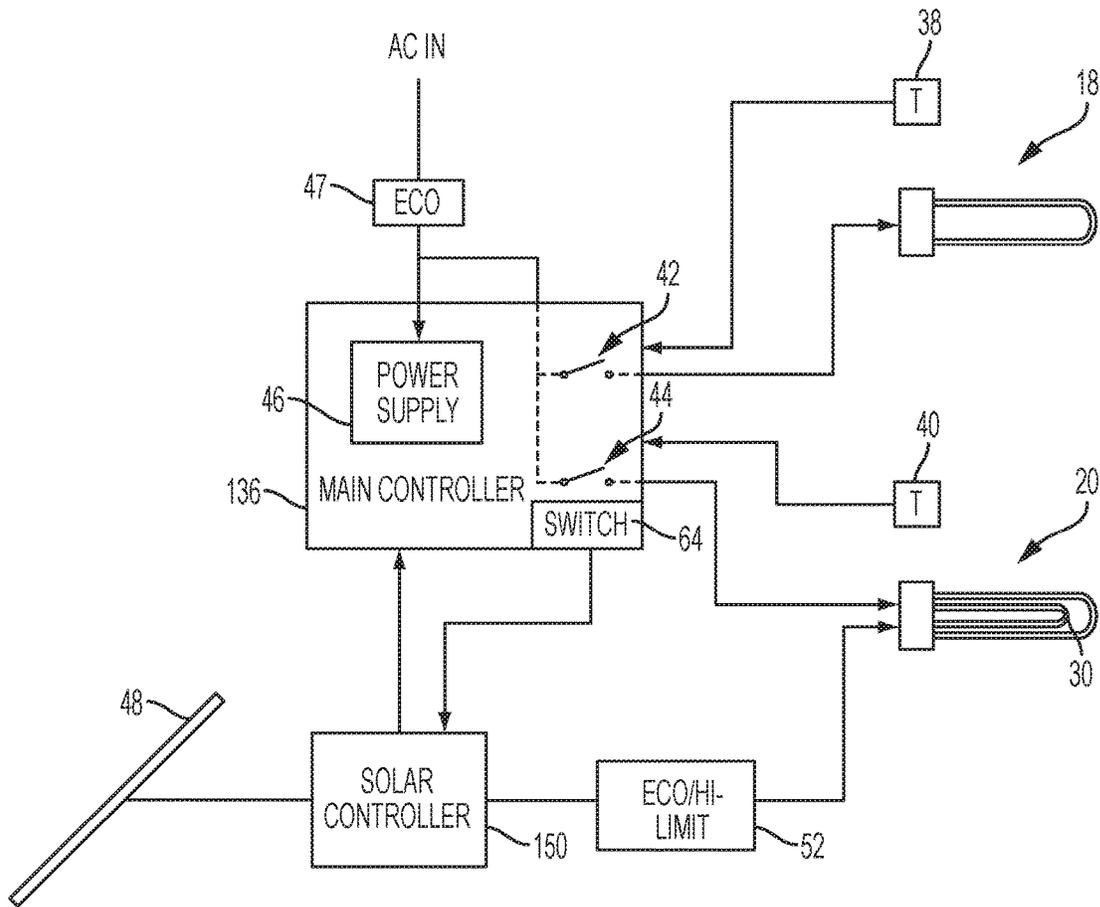


FIG. 5

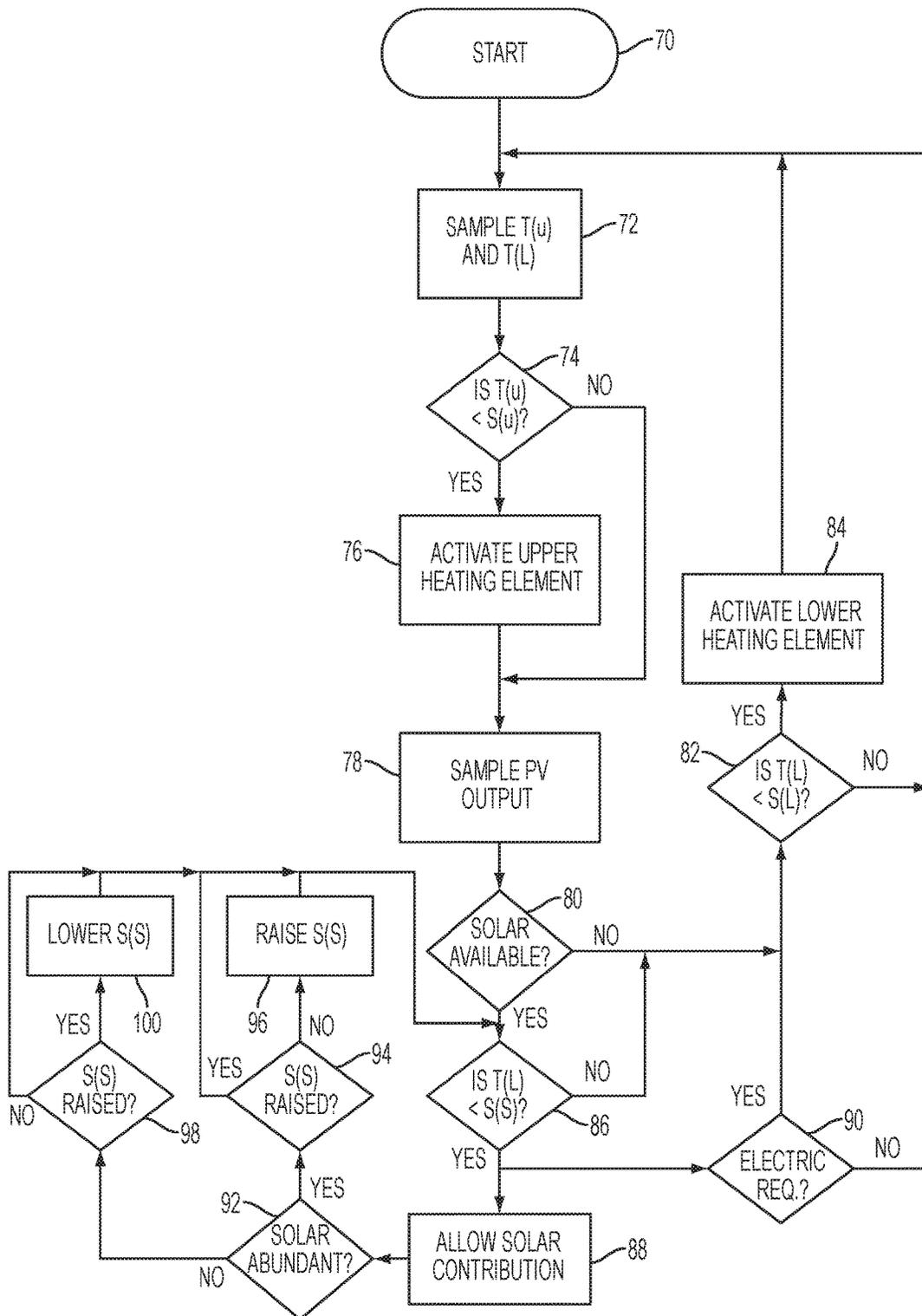


FIG. 6

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**WATER HEATER HAVING A
SUPPLEMENTAL PHOTOVOLTAIC
HEATING ARRANGEMENT**

CLAIM OF PRIORITY

This application claims priority to U.S. Provisional Application No. 62/099,529, filed Jan. 4, 2015, the entire disclosure of which is incorporated by reference herein.

BACKGROUND OF THE INVENTION

The present invention relates generally to water heaters. More particularly, the present invention relates to a water heater in which a primary heating arrangement (e.g., electric or gas) is supplemented by a photovoltaic heating arrangement.

Typical water heaters have a tank in which a quantity of heated water is maintained for use as needed. Generally speaking, such water heaters fall into one of two categories, i.e., electric or gas, depending on the type of heat source used to bring the water in the tank up to the desired temperature. Electric water heaters, for example, are often configured having two electric heating elements near the top and the bottom of the tank, respectively. Typically, the heating elements are energized by AC voltage (such as 240 VAC or others) which is turned on and off as necessary to maintain the desired temperature.

In this regard, electronic or bimetallic thermostats are used to regulate the water temperature by sensing the water temperature and allowing the voltage to be applied to the heating element(s) when heat is needed. Heat loss over a period of time (i.e., standby loss) or usage of the water heater capacity determines the demand for hot water. Thus, tanks that exhibit greater heat loss in the idle state are less efficient than those that exhibit less standby heat loss because more electric (or gas) energy is required to maintain the desired temperature. Efforts have thus been made to increase efficiency by providing better insulation for the tank. However, even very well insulated water heaters experience some standby loss.

The present invention recognizes the foregoing considerations, and others, of the prior art.

SUMMARY OF THE INVENTION

According to one aspect, the present invention provides a water heater comprising an insulated tank having a water inlet and a water outlet, and further defining an interior volume to contain a quantity of water. A primary heating arrangement applies heat energy to the water so as to heat the water. In addition, the primary heating arrangement is configured to maintain the water during standby periods between upper and lower set point temperatures.

A supplemental heating arrangement, operative to supply additional heat energy to the water in order to lessen energy usage by the primary heating arrangement during the standby periods, is also provided. In accordance with a preferred embodiment, the supplemental heating arrangement includes at least one photovoltaic panel and a supplemental heating element. Control electronics are operatively interposed between the at least one photovoltaic panel and the supplemental heating element.

In many cases, the primary heating arrangement may comprise at least one primary heating element adapted to be energized by AC power. For example, the primary heating arrangement may comprise first and second heating ele-

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ments located near the top and bottom of the tank, respectively. Typically, first and second thermostats will be respectively associated with the first and second heating elements. For example, the thermostats may comprise bimetallic thermostats or thermistors depending on the embodiment. According to some embodiments, the primary heating arrangement may comprise an electronic processor-based control system operative to control individually the first and second heating elements. In addition, the control system can operate the supplemental heating arrangement in response to tank conditions. The control electronics of the supplemental heating arrangement may comprise a maximum power point tracking (MPPT) controller.

According to an exemplary embodiment, the second heating element may comprise a primary resistive element and the supplemental heating element. The supplemental heating arrangement may further comprise a high temperature limit switch operative to disconnect application of photovoltaic energy if a predetermined threshold temperature is reached.

Another aspect of the present invention provides a water heater comprising a tank defining an interior volume to contain a quantity of water. A primary heating arrangement, comprising at least one primary resistive element energized by AC power, applies heat energy to the water so as to heat the water. In this case, the primary heating arrangement further includes at least one thermostat to detect water temperature.

The water heater also has a supplemental heating arrangement operative to supply additional heat energy to the water in order to lessen energy usage by the primary heating arrangement. The supplemental heating arrangement includes at least one photovoltaic panel, a supplemental heating element, and control electronics operatively interposed between the at least one photovoltaic panel and the supplemental heating element. A main controller is in electrical communication with the primary heating arrangement and the control electronics of the supplemental heating arrangement so as to control selectively heating at the at least one primary resistive element and the supplemental heating element.

In some embodiments, the control electronics of the supplemental heating arrangement are contained in a separate housing from the main controller. Embodiments are also contemplated wherein the control electronics of the supplemental heating arrangement are integrated into the main controller.

An additional aspect of the present invention provides a method of controlling operation of a water heater having a primary heating arrangement that functions to maintain water temperature during standby periods between a predetermined upper set point temperature and a predetermined lower set point temperature. One step of the method involves providing a solar heating arrangement operative to supply additional heat energy to the water in order to lessen energy usage by the primary heating arrangement, the solar heating arrangement including electronics operative to detect availability of solar energy. According to another step, a determination is made of whether abundance of solar energy at a particular time exceeds a threshold. If the abundance of solar energy exceeds the threshold, raising at least the lower set point temperature. According to a further step, heat energy from the solar heating arrangement is applied to water contained within the water heater if the water temperature is between the upper set point temperature and the lower set point temperature.

According to exemplary methodology, the primary heating arrangement may be temporarily disabled when heat energy from the solar heating arrangement is applied. In some cases, the primary heating arrangement may be operated to apply heat energy when additional heat energy from the solar heating arrangement is also applied. Exemplary methodology contemplates determining whether one of the upper set point temperature and lower set point temperature has already been raised if the abundance of solar energy does not exceed the threshold. If one of the upper set point temperature and lower set point temperature has already been raised, it can be lowered to a default value.

Another aspect of the present invention provides a method of controlling operation of a water heater having a primary heating arrangement. According to one step, a solar heating arrangement operative to supply additional heat energy to the water in order to lessen energy usage by the primary heating arrangement is provided. A determination is made of whether solar energy is available at a particular time. If the solar energy is available, heat energy is applied from the solar heating arrangement to water contained within the water heater. While heat energy is being applied from the solar heating arrangement, the primary heating arrangement is selectively operated to also supply heat energy to the water.

Other objects, features and aspects of the present invention are provided by various combinations and subcombinations of the disclosed elements, as well as methods of practicing same, which are discussed in greater detail below.

BRIEF DESCRIPTION OF THE DRAWINGS

A full and enabling disclosure of the present invention, including the best mode thereof, to one of ordinary skill in the art, is set forth more particularly in the remainder of the specification, including reference to the accompanying drawings, in which:

FIG. 1 is a diagrammatic representation of a water heater constructed in accordance with an embodiment of the present invention.

FIG. 2 is a block diagram showing certain aspects of the water heater of FIG. 1.

FIG. 3 is a side elevation of a dual-sheath heating element that can be used in accordance with embodiments of the present invention to allow primary electric heating and photovoltaic supplemental heating.

FIG. 4 is a diagrammatic representation of a heating arrangement in accordance with a first alternative embodiment of the present invention.

FIG. 5 is a block diagram of a heating arrangement in accordance with a second alternative embodiment of the present invention.

FIG. 6 is a flowchart showing an exemplary method by which the embodiment of FIG. 5 may be operated.

Repeat use of reference characters in the present specification and drawings is intended to represent same or analogous features or elements of the invention.

DETAILED DESCRIPTION OF PREFERRED EMBODIMENTS

It is to be understood by one of ordinary skill in the art that the present discussion is a description of exemplary embodiments only, and is not intended as limiting the broader aspects of the present invention, which broader aspects are embodied in the exemplary constructions.

Presently-described embodiments provide a water heater having a supplemental photovoltaic (e.g., solar) heating arrangement which at least partially offsets standby losses that might otherwise occur. The energy produced by one or more relatively small and easily-installable photovoltaic panels preferably contributes energy equal to or greater than typical standby loss. Because modern water heaters are generally well-insulated, this can often be achieved by a solar energy contribution which is less than about 5% of the water heater's total energy consumption. Water heaters constructed in accordance with the present invention may often achieve an Energy Factor (EF) of greater than 1.0.

Referring now to FIG. 1, a water heater **10** constructed in accordance with an embodiment of the present invention is illustrated. Water heater **10** includes an insulated tank **12** capable of containing a fixed volume of water, e.g., 20, 40, or 50 gallons. Heated water is discharged through an outlet **14**, while colder water enters the tank through an inlet **16**. Often, inlet **16** will be configured such that the incoming water will enter and mix with the existing water near the bottom of the tank.

Referring now also to FIG. 2, water heater **10** includes top and bottom heating elements **18** and **20** mounted to the tank. In this regard, each of heating elements **18** and **20** includes a resistive element **22** and **24** that loops into the interior volume of the tank from a respective mounting flange **26** and **28**. Application of AC energy (e.g., 240 VAC) to resistive elements **22** and **24** causes them to heat in conventional fashion. In this case, however, heating element **20** includes a supplemental resistive element **30** to which supplemental photovoltaic energy is applied to offset standby losses in the tank. (One skilled in the art will appreciate that FIG. 2 is a simplified block diagram in which electrical connections that may actually be two or more lines are shown as a single line.)

Additional detail regarding a preferred embodiment of heating element **20** can be seen in FIG. 3. As shown, resistive element **24** turns back in order to increase its overall length, and thus the heated surface area exposed to the water. In this embodiment, resistive element **30** has a shorter overall length because it is intended to supplement the heating provided by the primary AC heating arrangement. A pair of connection terminals, e.g., terminal **32**, provides electrical connection between resistive element **24** and a source of AC energy. Likewise, a pair of connection terminals, e.g., terminal **34**, provides electrical connection between resistive element **30** and the photovoltaic source.

Referring again to FIGS. 1 and 2, water heater **10** in this embodiment includes an electronic controller **36** that operates resistive elements **22** and **24**. In this regard, respective electronic thermostats (e.g., thermistors) **38** and **40** detect the water temperature near heating elements **18** and **20**. This temperature information is fed to controller **36** and used to selectively turn resistive elements **22** and **24** on and off. In particular, controller **36** operates respective electrical switches **42** and **44** that connect or disconnect AC energy to resistive elements **22** and **24**, respectively. Switches **42** and **44** may be any suitable type of normally open switching device that may be operated by controller **36**, such as a suitable solid state or solenoid controlled switch. Controller **36** includes a DC power supply **46** also in electrical communication with the AC power source through an electrical cut-off (ECO) **47**. As one skilled in the art will recognize, ECO **47** removes electrical power from the water heater in the event of an over-temperature condition. Typically, an ECO, once opened, must be manually reset.

Preferably, controller **36** includes a processor implementing instructions (e.g., firmware) that will turn on resistive elements **22** and **24** at different times in order to achieve the desired results. For example, if hot water in the tank has been used, controller **36** may first turn on resistive element **22** while leaving resistive element **24** off. This heats water near the top of the tank (where hot water discharges) so that some hot water is available more quickly. After the water at the top of the tank has been heated, resistive element **22** turns off and, depending on the temperature detected at thermostat **40**, resistive element **24** may be turned on. When the desired temperature at the bottom of the tank is also reached, both of the AC resistive elements will be off. Without any supplemental heating as described herein, the tank temperature will gradually decrease due to escaping heat. Once the temperature drops by a predetermined amount (e.g., 15-20 degrees F.), resistive heating is again applied to bring the water temperature back up to target. If no water is used, this cycle of heating and slow cooling repeats in "saw tooth" fashion.

In accordance with the present invention, such standby losses can be at least partially offset using supplemental photovoltaic energy. Specifically, the illustrated embodiment utilizes one or more photovoltaic panel(s) **48** mounted at a suitable location for exposure to solar energy. For example, photovoltaic (PV) panel **48** may be placed on a homeowner's roof in an orientation likely to receive the most energy from the sun. The energy yielded by photovoltaic (PV) panel **48** is preferably conditioned using a suitable solar controller **50** for application to resistive element **30**. According to a preferred embodiment, for example, controller **30** may be a maximum power point tracking (MPPT) controller. Such controllers operate as DC-to-DC converters to optimize matching between PV panel **48** and the resistive load. Although solar controller **50** is shown as a separate device in the drawing, one skilled in the art will appreciate that it can be integrated into PV panel **48**.

In this embodiment, the supplemental solar heating arrangement operates independently of controller **36**. Thus, the additional heat provided by resistive element **30** will not be dictated by controller **36**, but will reduce the need in standby for controller **36** to turn on resistive elements **22** and **24**. In order to ensure that PV panel **48** does not overheat the water, a high temperature limit switch **52** is provided. Switch **52** is normally closed, but will open in the event that the water temperature reaches a predetermined threshold. For example, switch **52** may be a bimetallic switch, attached to tank **12** at a suitable location, that opens mechanically when the temperature threshold is reached. In this embodiment, switch **52** is configured as an ECO which must be manually reset once tripped.

As an example, panel **48** may generate up to 235 W of power with good exposure to sunlight. In this case, controller **50** can operate to provide 8-10 amps of DC current at a nominal 24 VDC. One commercially available solar controller believed to be suitable for this purpose is the PPT 12/24 solar controller from Solar Converters Inc., located in Guelph, Ontario, Canada. As available, the supplemental energy is supplied continuously to tank **12** subject to being cut-off if high-limit switch **52** detects excessive temperature.

Referring now to FIG. 4, a supplemental heating arrangement similar to that shown in FIGS. 1 and 2 is incorporated into a water heater utilizing traditional bimetallic thermostats. In this regard, the thermostat for top heating element **18** is incorporated into a first switching unit **54** which includes the ECO for the AC power connection. The thermostat for the AC portion of bottom heating element **20** is

incorporated into a second switching unit **56**. The respective temperature set points of the top and bottom thermostats, and the manner in which switching units **54** and **56** are interconnected, achieve the desired operation.

In this regard, AC energy enters first switching unit **54** through a normally closed high-limit switch **58**. The state of the top thermostat determines whether the switch **60** connects between terminals "1" and "4," or between terminals "1" and "2." If the switch position is between terminals "1" and "2," then heating element **18** is energized. If the switch position is between terminals "1" and "4," heating element **18** is not energized but energy is provided to second switching unit **56**. The state of the bottom thermostat determines whether switch **62** of second switching unit **56** is in an open or closed position. If switch **62** is in the closed position, then resistive element **24** of heating element **20** is energized.

As shown, solar controller **50** supplies energy to supplemental element **30** of heating element **20** on a continuous basis as solar energy is available. This is subject to high-limit switch **52**, which cuts off the supply of solar energy if the water temperature reaches a threshold. FIG. 4 shows greater detail regarding the specific wiring pattern between PV panel **48** and solar controller **50** for the exemplary PPT 12/24 solar controller mentioned above. One skilled in the art will appreciate that the wiring pattern will likely change if a different solar controller is employed.

Embodiments are also contemplated in which the solar controller supplies information to and/or operates under the control of the main water heater controller in order to achieve improved results. In some such embodiments, for example, the functionality of the solar controller could be incorporated into the main controller. In other embodiments, a separate solar controller could be provided but it is in operative communication with the main controller.

In this regard, FIG. 5 illustrates an alternative embodiment in which a solar controller **150** is in operative communication with a water heater controller **136**. (The reference numbers for these components are increased by one hundred in comparison with their counterparts in FIG. 2 to indicate they are modified.) Controller **136** controls switches **42** and **44** for the AC resistive elements, and also controls whether solar controller **150** supplies energy for the supplemental element **30**. This is diagrammatically represented by an internal "switch" **64** by which the controller **136** instructs the solar controller **150** to stop working. Thus, controller **136** functions to apply energy from the AC source and the supplemental solar source in order to enhance overall efficiency.

For example, as illustrated in FIG. 6, controller **136** may execute program instructions which dynamically change temperature set points on a temporary basis in order to take advantage of abundant solar energy when it is available. Typically, the set points will increase a moderate amount (e.g., a few degrees) in order to alleviate any concerns about the water getting too hot. For example, the upper set point may not change but the lower set point can be raised if solar energy is abundant.

According to this example, the process begins at step **70**, and proceeds at step **72** to sample temperature at the top ("T(u)") and bottom ("T(L)") of the tank. At step **74**, a decision is made whether T(u) is less than the upper set point "S(u)." If so, the upper heating element is activated at step **76**. If not, the photovoltaic (PV) output is sampled at step **78** to determine at step **80** whether a solar contribution can be made. As should be understood in view of the present disclosure, the maximum power point tracking solar controller **150** controls the load resistance presented to photo-

voltaic panel **48** to draw the maximum power from panel **48** as illumination to the panel varies. Nonetheless, there will be a point at which controller **50** will not be able to provide the nominal voltage to be provided by the controller, e.g. 12 Vdc or 24 Vdc. Solar controller **150** detects and reports this condition to controller **136**.

If solar contribution is not available, a determination is made at step **82** of whether T(L) is less than the lower set point S(L). If so, the lower AC element is activated at step **84**. If not, the process loops back to Start. If sufficient solar energy is available, a determination is made at step **86** of whether T(L) is less than a solar set point S(S). If so, solar contribution is allowed (i.e. controller **136** controls controller **150** to apply its output voltage and current to supplemental element **30** with ECO **52**) as shown at step **88**. In addition, as shown at step **90**, a determination is made of whether AC heating is also required because of demand or the like.

In the event that a solar contribution is allowed, a determination is made at step **92** of whether solar energy is particularly abundant at the moment. As should be understood in view of the present disclosure, solar controller **150** detects power available from panel **48** and, thus, provides information to controller **136** of the panel's ability to provide power sufficient to provide the controller's output voltage level (e.g. 12 Vdc or 24 Vdc). Accordingly, controller **136** may determine if the power available from panel **48** is sufficiently above the minimum needed to provide the desired output voltage to the supplemental element such that the solar set point should be raised. The level at which available solar power from the panel is sufficient to trigger the solar set point increase is selected at the operator's desire. If so, the process will raise the solar set point S(S) on a temporary basis to take advantage of the additional "free" energy. This is indicated at step **94**, where it is determined whether the solar set point has already been raised. If not, as indicated at step **96**, the set point S(S) is raised. If abundant solar energy is not available, the solar set point remains at the lower level, or is lowered back to its default value (as indicated at steps **98** and **100**). It will be appreciated that set point S(S) may or may not be equal to S(L) depending on the exigencies of a particular application.

It can thus be seen that the present invention provides a water heater arrangement that exhibits improved efficiency and energy factor by the use of a supplemental photovoltaic heating arrangement. While preferred embodiments of the invention have been shown and described, modifications and variations may be made thereto by those of ordinary skill in the art without departing from the spirit and scope of the present invention. For example, while the above description is primarily directed to an electric water heater having a supplemental photovoltaic heating arrangement, those skilled in the art will recognize that principles of the present invention may be used with gas water heaters as well. In addition, it should be understood that aspects of the various embodiments may be interchanged both in whole or in part. Furthermore, those of ordinary skill in the art will appreciate that the foregoing description is by way of example only, and is not intended to be limitative of the invention.

What is claimed is:

1. A water heater comprising:

an insulated tank having a water inlet and a water outlet, said tank further defining an interior volume to contain a quantity of water;

a primary heating arrangement disposed with respect to the tank to apply heat energy to the water to heat the water, said primary heating arrangement configured to

maintain the water during standby periods between upper and lower set point temperatures;

a supplemental heating arrangement disposed with respect to the tank to apply additional heat energy to the water to lessen energy usage by said primary heating arrangement during the standby periods, said supplemental heating arrangement including

at least one photovoltaic panel,

a supplemental heating element, and

control electronics operatively interposed between said at least one photovoltaic panel and said supplemental heating element; and

a controller in electrical communication with the primary heating arrangement and the control electronics of the supplemental heating arrangement to selectively control heating at the primary heating arrangement and the supplemental heating arrangement, wherein said controller is operative to adjust at least one of said upper and lower set point temperatures in response to changes in available energy from said at least one photovoltaic panel.

2. The water heater as set forth in claim **1**, wherein said primary heating arrangement comprises at least one primary heating element adapted to be energized by AC power.

3. The water heater as set forth in claim **2**, wherein said primary heating arrangement comprises first and second heating elements located near a top and a bottom of the tank, respectively.

4. The water heater as set forth in claim **3**, wherein said primary heating arrangement comprises first and second thermostats associated with said first and second heating elements, respectively.

5. The water heater as set forth in claim **4**, wherein said first and second thermostats comprise bi-metallic mechanical thermostats.

6. The water heater as set forth in claim **4**, wherein said first and second thermostats comprise thermistors.

7. The water heater as set forth in claim **4**, wherein said second heating element comprises a primary resistive element and said supplemental heating element.

8. The water heater as set forth in claim **1**, wherein said controller is configured to operate said supplemental heating arrangement in response to tank conditions.

9. The water heater as set forth in claim **1**, wherein said supplemental heating arrangement further comprises a high temperature limit switch operative to disconnect application of photovoltaic energy if a predetermined threshold temperature is reached.

10. The water heater as set forth in claim **1**, wherein said control electronics of said supplemental heating arrangement comprise a maximum power point tracking (MPPT) controller.

11. A water heater comprising:

a tank defining an interior volume to contain a quantity of water;

a primary heating arrangement comprising at least one primary heating element disposed with respect to the tank to apply heat energy to the water to heat the water, said primary heating arrangement comprising at least one primary resistive element energized by AC power, said primary heating arrangement including at least one thermostat to detect temperature of the water;

a supplemental heating arrangement operative to supply additional heat energy to the water to lessen energy usage by said primary heating arrangement, said supplemental heating arrangement including at least one photovoltaic panel,

a supplemental heating element, and control electronics operatively interposed between said at least one photovoltaic panel and said supplemental heating element; and

a controller in electrical communication with said primary heating arrangement and said control electronics of said supplemental heating arrangement to selectively control heating at said at least one primary heating element and said supplemental heating element, wherein the controller is operative to maintain said water temperature during standby periods between upper and lower set point temperatures and to raise at least the lower set point temperature in response to a level of available energy from the at least one photovoltaic panel.

12. The water heater as set forth in claim 11, wherein said control electronics of said supplemental heating arrangement are contained in a housing separate from said controller.

13. The water heater as set forth in claim 11, wherein said control electronics of said supplemental heating arrangement are integrated into said controller.

14. The water heater as set forth in claim 11, wherein said at least one primary heating element comprises first and second primary resistive elements located near a top and a bottom of the tank, respectively.

15. The water heater as set forth in claim 14, wherein said controller is operative to selectively energize said first and second primary resistive elements at respective different times.

16. The water heater as set forth in claim 15, wherein said controller is operative to selectively operate said supplemental heating arrangement during times in which said second primary resistive element is also energized.

17. A method of controlling operation of a water heater having a primary heating arrangement that is operative to apply heat energy to water contained within the water heater to maintain temperature of the water during standby periods between a predetermined upper set point temperature and a predetermined lower set point temperature, said method comprising steps of:

- providing a solar heating arrangement operative to apply additional heat energy to the water to lessen energy usage by the primary heating arrangement, said solar heating arrangement including electronics operative to detect availability of solar energy;
- determining whether abundance of solar energy at a particular time exceeds a threshold;
- if the abundance of solar energy exceeds the threshold, raising at least the predetermined lower set point temperature; and
- applying heat energy from the solar heating arrangement to the water if the water temperature is between the predetermined upper set point temperature and the predetermined lower set point temperature.

18. The method as set forth in claim 17, further comprising the step of temporarily disabling the primary heating arrangement when heat energy from the solar heating arrangement is applied.

19. The method as set forth in claim 17, further comprising the step of operating the primary heating arrangement to

apply heat energy to the water when the additional heat energy from the solar heating arrangement is also applied.

20. The method as set forth in claim 17, further comprising steps of:

- if the abundance of solar energy does not exceed the threshold, determining whether one of the predetermined upper set point temperature and the predetermined lower set point temperature has already been raised; and
- if one of the predetermined upper set point temperature and the predetermined lower set point temperature has already been raised, lowering it to a default value.

21. The method as set forth in claim 17, wherein said solar heating arrangement comprises:

- at least one photovoltaic panel;
- a supplemental heating element; and
- control electronics operatively interposed between said at least one photovoltaic panel and said supplemental heating element.

22. A method of controlling operation of a water heater having a primary heating arrangement that is operative to apply heat energy to water contained within the water heater, said method comprising steps of:

- providing a solar heating arrangement operative to apply additional heat energy to the water to lessen energy usage by the primary heating arrangement;
- determining whether solar energy is available at a particular time;
- if the additional heat energy is available, applying the additional heat energy from the solar heating arrangement to the water;
- while the additional heat energy is being applied from the solar heating arrangement, selectively operating the primary heating arrangement to also supply heat energy to the water to maintain a temperature of the water between upper and lower set point temperatures; and
- wherein a controller is operative to adjust at least one of the upper and lower set point temperatures in response to changes in availability of said additional heat energy.

23. The method as set forth in claim 22, further comprising the step of temporarily disabling the primary heating arrangement when the additional heat energy from the solar heating arrangement is applied.

24. The method as set forth in claim 22, further comprising steps of:

- if the solar energy does not exceed a threshold, determining whether one of the upper set point temperature and lower set point temperature has already been raised; and
- if one of the upper set point temperature and lower set point temperature has already been raised, lowering it to a default value.

25. The method as set forth in claim 22, wherein said solar heating arrangement comprises:

- at least one photovoltaic panel;
- a supplemental heating element; and
- control electronics operatively interposed between said at least one photovoltaic panel and said supplemental heating element.

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